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Analysis of the energy intensity evolution in the Brazilian industrial sector—1995 to 2005

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ABSTRACT

This study developed a method to evaluate the evolution of energy intensity in the Brazilian industrial sector from 1995 to 2004. In order to do so, it was necessary to obtain six different measures (indicators) of the sector energy intensity. Considering the concept of energy intensity as the ratio between energy consumption and the level of economic activity, two measures were used for the energy consumption: a thermal (physical) and an economic one. For the level of economic activity, three measures were used: value of production, value of delivered goods and added value. In the Brazilian industrial sector, most of these indicators have behaved in a similar way. In a disaggregated way, energy intensity indicators show a unified direction of its evolution. However, a more elaborate study on the consumption profile of the Brazilian industrial sector and its economical activities indicates the presence of important deviations concerning the annual rate of change in energy intensity. Besides, there is no evident relation between these deviations and the composition of the different indicators of energy intensity.

Contents

1. Introduction

Energy is a fundamental input for the social and economic development of a country. The lack of supply of this input may trigger several crises for a nation, mainly in the (micro and macro) economic ambit, placing it in a frail position before the external competition and increasing the energy dependence level.

Nowadays, economic frailty is synonymous to several qualifiers [6,11]. Among the main ones, recession can be detached, having as direct consequence unemployment and increase in poverty. Several efforts have been made aiming to establish indicators that related energy measures with economic activities. The most known (efficacious) and widely used is exactly energy intensity.

Energy intensity is an object of study in different world governments. The interest in this study is related, above all, with the concern of keeping sovereignty, in respect to the economic and, consequently, social stability. There is also a direct relationship between the energy intensity measure and the emission of greenhouse gases [8]. Many are the numerical models that aggregate these two concepts. In this sense, to measure the energy intensity becomes a fundamental factor in the importance related to environmental issues [7].

It is within this context [12] that most of the industrialized countries yearly publish an analysis on the evolution of energy intensity and, at the same time, the economic evolution of the main

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segments in the manufacturing sector, such as: pig iron, alloy iron, cement, textiles, food and beverages, etc.

In this work, an analysis on the evolution of the energy intensity in the Brazilian industrial sector was conducted comprising the period 1995–2004. So as to make this issue clearer, thinking of the "pure" concept of energy intensity, the ratio between energy consumption and economic activity, there are basically two trends for aggregation problems to be considered:

- Numerator (energy consumption): concerns energy consumption and the different possibilities of being expressed, due to the variety of energy sources.
- Denominator (economic activity): different possibilities for aggregating products, services and or economic activities are considered.

Six different ways for measuring energy intensity will be presented; they are two for the numerator, being one thermal and the other economic; three for the denominator: added value, value of delivered goods and production value.

2. Contextualization of the energy intensity concept [13]

The mathematical definition of the energy intensity concept is simple: the ratio between energy consumption and an economic activity. Another widely used concept for energy intensity is the measure of energy efficiency. Countries that present low levels of energy intensity are considered "energetically more efficient".

The improvement in energy efficiency is exactly one of the privileged means for reducing greenhouse gases emissions, essential for minimizing the negative impacts on the people's level of life. Moreover, modern techniques and "more efficient" equipment may also contribute to the competitivity in the prices of products and services.

Inserted in this scenario, most of the industrialized countries yearly publish an analysis of the evolution of energy intensity in the different sectors of economy, such as: industrial, transportation, agricultural, commercial, etc. Monitoring the evolution of energy intensity may contribute to decision taking in the public sphere, allows guiding public policies and reduces risks associated to enterprises of energy nature. Besides, it allows obtaining more information on the national economy sectors and, consequently, of the country itself as a whole.

For better contextualizing the energy intensity concept, it is necessary to recall the difference between global energy intensity and added energy intensity.[1]

According to Bernard and Côte [14]:

> [...] the global energy intensity is the real level of energy consumption per production unit or activity, whereas adjusted energy intensity is the level of energy consumption per production unit or activity, after taking into account the relative changes in production or activity among sectors or components of a sector [1, p. 2].

This adjustment is made so as to obtain a measure that better translates the evolution of energy efficiency. Still according to Bernard and Côte

> [...] global energy intensity is attributed not only to the changes in energy intensity at the level of the entities composing a segment of an economic activity, but also the division of production or activity among its entities [1, p. 2].

[1] This work used the same terminology as the energy efficiency control organism of the Canadian Government. See Ressources Naturalles Canada (2000, p. 8).

In this research, only the measure of global energy intensity of the Brazilian industrial sector will be considered. It is not an easy task to interpret the evolution in energy intensity of a country. In general, when faced with scientific problems, a simple case is cut out and a range of considerations are made about it, and later the knowledge obtained is applied to a more complex problem.

As an example, let us consider analyzing the evolution of energy intensity to produce a ton of steel. Or the gas consumed by an automobile to travel a certain distance. These situations would not require more than simple calculations to be analyzed and do not greatly contribute to the discussions and intrinsic problematics for a more complex case, as a sector in the Brazilian economy.

These upper aggregation levels encompass different forms of energy and a variety of products and services, considerably increasing the number of variables and hypotheses to be considered. For this reason, to study this level of aggregation turns difficult and, many times, uncertain [17]. The historical trajectory of this kind of aggregation problem in the existing literature shows that it is usual to identify a common factor that allows incorporating each of the elements subject to aggregation [4].

For energy consumption, there are two privileged approaches to measure its upper aggregation level. It is important to detach the different sources of energy, that is, oil byproducts and oil itself, natural gas, carbon, electricity and its byproducts.[2] The first method is that adopted by most of the governmental organisms and consists in converting the different sources of energy on a same base of thermal equivalence, as for example, the joule (J). The amount of heat per source of energy is the common factor that allows aggregation. Recent researches increasingly tend to favor the physical measures of activity (tons, liters, cubic meters, etc.), when these can be adequately measured.

Nevertheless, even when the physical measures can be used at the desired levels (disaggregated and aggregated), the economic nature measures emerge more strongly within the upper aggregation levels. This characteristic tends to favor the establishment of a standard consumption measure per national production unit such as the joule (J) per US$ of GDP.

The present work intends to conduct an analysis on the evolution of six energy intensity measures of the Brazilian manufacturing sector. Two measures can be detached for energy consumption (numerator), which are [5]:

- Thermal equivalence (amount of heat expressed in joule)—(I).
- Economic measure (price)—(II).

For the production or activity (denominator), three measures are evidenced:

- Added Value—(A).
- Value of Delivered Goods—(B).
- Production Value—(C).

To make the actions of this research clearer in what refers to analyzing the evolution of energy intensity according to six measures, the following scheme is presented:

1. Thermal Equivalence/Added Value.
2. Thermal Equivalence/Value of Delivered Goods.
3. Thermal Equivalence/Production Value.
4. Economic Measure/Added Value.
5. Economic Measure/Value of Delivered Goods.
6. Economic Measure/Production Value.

[2] Only the industries consumption of electricity and natural gas will be analyzed in this work.

When using this methodology, the ultimate purpose is to conduct a comparative analysis and verifying whether the six measures have similar behavior. Otherwise, the paths being generated must be analyzed and possible deviations must be cleared, according to the economic context of the industrial sector or even of the country itself. In other words, are these six measures of the evolution of energy intensity in the Brazilian industrial sector providing the same message?

Or else, in case the answer is negative, is it possible to identify the real systematic differences when using one or another of the six measures of energy intensity evolution? Is it possible to notice these differences for the Brazilian manufacturing sector or, comparatively, for the whole Brazilian economy?

3. Methodology [3]

In this research, except for slight adaptations to the Brazilian case, the methodology developed in the work called "L'intensité énergétique du secteur manufacturier de 1976 à 1996 – Québec, Ontario, Alberta, et Colombie – Britannique" [1][3] was applied.

4. Considerations as to the total energy consumption [10]

Most organizations produce their own information about energy consumption according to the formula below, which incorporates the thermal equivalence factors as an aggregation parameter:

$$E_t^{Ther} = \sum_i^N J_i E_{it} \tag{1}$$

Or yet:

E_t^{Ther} = aggregated amount of thermal energy expressed in heat value (Joules) by the span of time (t);
J_i = amount of thermal energy (Joules) per type i energy unit;
E_{it} = amount of type i energy used during the period t;
N = name of the type of energy.

The great problem verified when using this formula as a parameter for measuring the total energy consumption is related to the J_i factor. The thermal equivalence factors are measured on an experimental basis that is, having as a reference the amount of heat produced inside a laboratory.

Considering the real use situations, when applying this formula, some factors are not taken into account. A fundamental factor and of high relevance such as the dissipation of heat in the conversion of the sources of energy into work conducted are not accounted for. This unforeseen fact may lead this measure to undesirable errors.

A main and extremely relevant factor and which is linked to the [16] greatest difficulty in using this formula is related to "the fact that all the forms of energy are considered equivalent as to the heat produced" [1]. Having as a principle that all sources of energy may be summarized simply as the "amount of heat" they produce (considering only this aspect) is to say: it turns possible for the consumer to replace a source of energy for another one with no problem whatsoever, be it technical, financial, etc. It is evident that this is not verified in real situations.

There are several formulas of indexes that incorporate the prices as weights. In conformity with the methodology applied in this work,[4] the Theil index[5] will be used, from which the change in period $t-1$ to period t is defined as follows:

$$\frac{I_t^{Theil}}{I_{t-1}^{Theil}} = \prod_i^n \left(\frac{E_{it}}{E_{it-1}}\right)^{w_{it}^*} \tag{2}$$

Or:

I_t^{Theil} = the Theil index to period t;
$W_{it}^* = [1/2(w_{it}+w_{it-1})w_{it}w_{it-1}]^{1/3} / \sum_i^N [1/2(w_{it}+w_{it-1})w_{it} w_{it-1}]^{1/3}$ = weights related to the source of energy i to the period t;
$w_{it} = p_{it}E_{it} / \sum_i^N p_{it}E_{it}$ = part of the expense of the source of energy i to period t;
p_{it} = price of the source of energy i to period t.

Concerning this formula:

"As every Tornqvist index, the Theil index is part of a family of indexes that constitute since discrete approximations of the continuous Divisa index.[6] The great advantage of the Theil formula is that it allows the introduction and the removal of sources of energy along the period of observation; it is a phenomenon regularly produced by the manufacturing industries [...]" [1, p. 9].

5. Considerations concerning the Brazilian industrial sector production

An analysis is now made on the relationship among the three concepts previously described for production or economic activity. That is, the production value, the value of the delivered goods and the added value. The analyses were conducted according to the following formulas[7]:

PV_t = production value in constant currency.

VL_t = delivery value in constant ($) currency.

$$= PV_t - I_t \tag{3}$$

Or:
I_t = change of inventories in constant ($) currency.

AV_t = added value in constant ($) currency.

$$= PV_t - C_t \tag{4}$$

Or:
C_t = cost of the intermediary means (material and energy) in constant ($) currency.

The mathematical ratios (3) and (4) show that the production value can be expressed by a composition of the value of the goods delivered and the added value. On the contrary, one or the other of these economic measures of manufacturing activity has a dimension that establishes a proportional difference for the production value. That is, the replacement of the inventories by the value of the delivered goods and their purchase of intermediary goods by the added value.

Along an economy cycle, these variables may adopt different behaviors and thus create deviations among the production measures or economic activity. There is not a perfect relationship among these three economic measures of manufacturing activity.

[3] The energy intensity in the manufacturing sector from 1976 to 1996—Quebec, Ontario, Alberta, and British Columbia.
[4] See [1, p. 8].
[5] Theil [18].
[6] Under certain conditions, these indexes constitute approximations borrowed from the economic theory. See [19, p. 19].
[7] The present approximations were adapted for Freeman et al. [2].

More closely examining the variables that are within a real production level:

$$PV_t = \frac{(Q_t \cdot P_t)}{IP_t}$$

Or:

Q_t = vector of goods produced by an industry in the period t;
P_t = vector of the current price corresponding to the goods in period t;
$Q_t \cdot P_t$ = vectorial product of Q_t and P_t;
IP_t = price index for a certain industry in period t.

The real production level is evidenced together with the goods produced Q_t, which are weighted by its respective value IP_t. The joint changes in these prices are taken into account by the price index IP_t, which is a weighted mean of these very prices P_t.

The variations of PV_t are, therefore, the result not only from changes at the real activity level Q_t, but also of its weighting by its prices. It will thus seem that all forms of aggregation imply part of information, and the production value is not more than a perfect combination of a physical measure of manufacturing activity. This process is accelerated the more the products are considered.

After having supported the "point of view" that the production value is the best replacement concerning the physical measures of the manufacturing production, Freeman et al. [2] have verified that this "point of view" is confirmed in practice. It becomes necessary to assess the laws existing among the three economic measures of activity presented previously and the physical level of production of the Brazilian industries. It is worth stressing that it is not possible to measure production in the physical units of all Brazilian industries.

6. Results obtained

Table 1 presents, in terms of the methodology used for this research, the results obtained from formula (1). This formula concerns the energy consumption in the Brazilian industrial sector. As described before, owing to the diversity of existing sources of energy, the need for an aggregation factor is fundamental for the calculations. In this case, as well as in most publications in industrialized countries, the joule was used.

The data above were taken from the National Energy Balance (BEN). It is important to state that the measure unit used to standardize data related to energy consumption in BEN is the toe (ton of oil equivalent). The unit conversion factor, toe to joule (J), was the same for all years.

Table 1
Energy consumption in TJ.

	Period					
	1995	2000	2001	2002	2003	2004
Energy consumption	2155	2562	2575	2736	2862	3023

Source: BEN. The calculations of the conversions were conducted by the authors, as well as in Table 2.

Table 2
Energy consumption in TJ.

	Year					
	1995	2000	2001	2002	2003	2004
Electricity	458	528	502	549	579	619
Natural gas	87	162	191	234	245	279

Source: BEN.

Table 3
Theil index.

1994/5	1995/6	2000/1	2001/2	2002/3	2003/4
1.02	1.037	0.9455	1.073	1.034	1.058

Source: BEN.

Table 4
PV–AV–VL (US$ $\times 10^6$).

	Period					
	1995	2000	2001	2002	2003	2004
V. Production	132.8	208.4	231.1	238.3	316.9	344.6
V. Aggregated	101.9	133.9	124.6	126.1	162.9	210.6
V. Deliveries	24.27	43.65	49.23	57.26	76.77	108.8

Calculations conducted by the authors.

Table 2 presents the electric energy and the natural gas consumption of the Brazilian industrial sector in the study period proposed. The research detaches these two sources of energy for the importance they have for the sector. First for their being prioritized in the calculations deriving from the methodology proposed.[8] Secondly, for being electricity a traditional source of energy used by industries and, as compared to the other sources, for accounting for the largest share of energy consumption[9] by the industries.

In the case of natural gas, after the construction and implementation of the gas duct Bolivia-Brazil, this energy input has become one of the main sources of energy for industrial use. It is worth remarking that this gas duct comprehends the main Brazilian consuming parks (southeast and south). Both regions are known for counting on a diversified and ample industrial park.

Table 3 shows the results obtained for the Theil index. It should be noted that the calculation for this index included in its formula the prices and the final consumption for each source of energy (natural gas, electricity, coal, etc). It is important to stress that all sources of energy are considered and accounted when using this index; however, not all of them are used as fundamental parameters.

The difficulty found when working with this methodology is related to the data and the way they are placed. In this specific case, for example, it was not possible to compute the price of some sources of energy. This occurs due to the difficulty in obtaining historical series of prices for some of them.

This does not happen for the energy consumption. These data are efficiently disaggregated in the BEN database. Nevertheless, the historical prices series of the sources of energy are not complete. Even so, the series available are not totally disaggregated.

The greatest difficulty found in the conduction of Theil index calculation lies exactly in the comparison of data related to the energy consumption of the industries and in the way these are disaggregated, with the historical prices series of the sources of energy available.

In BEN, the energy consumption is disaggregated in 17 sources of energy. In turn, the historical series of the prices for the sources of energy are disaggregated in 12. Furthermore, this does not mean that the 12 historical price series are the same made available for the energy consumption. For example, for the historical series,

[8] In the case of the Theil index, all the sources of energy are accounted and considered. However, not all of them are taken as reference parameter. In the case of this study, only electricity and natural gas were analyzed as such.

[9] For 2004, the total energy consumption in the industrial sector was responsible for 37.8% of the total energy consumption in Brazil. From this percentage, electricity accounted for 20.5%. In turn, natural gas accounted for 9.2%.

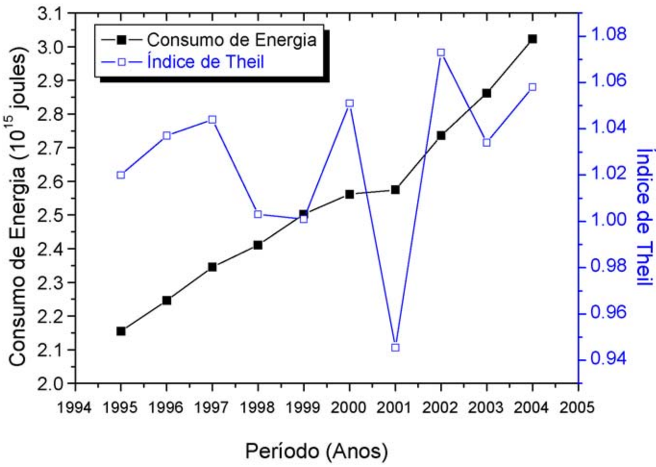

Fig. 1. Energy consumption × Theil index.

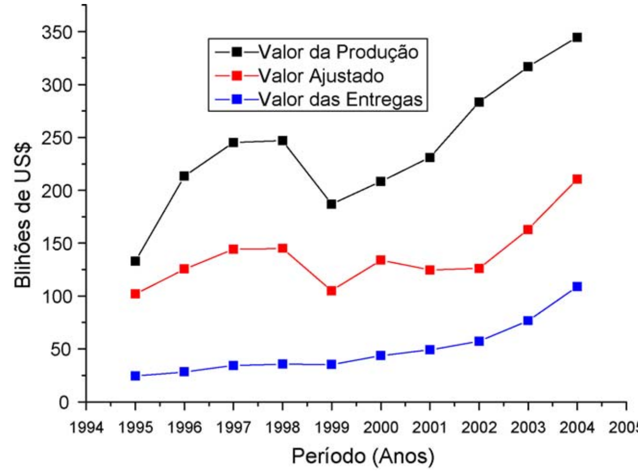

Fig. 2. Production Value, Added Value and Delivery Value.

Table 5
Six energy intensity measures.

	Theil index divided by (*)			Joules divided by (**)		
	Production V.	Added V.	Deliveries V.	Production V.	Added V.	Deliveries V.
1995	0.767732	1.000119	4.201214	0.162223	0.211327	0.887726
2000	0.504268	0.784600	2.407717	0.122925	0.191261	0.586927
2001	0.408975	0.758664	1.920218	0.111394	0.206640	0.523015
2002	0.450197	0.850586	1.873860	0.114816	0.216929	0.477899
2003	0.326277	0.634481	1.346709	0.090305	0.175608	0.372734
2004	0.306979	0.502216	0.971645	0.087712	0.143497	0.277626

Calculations conducted by the authors. The measure unit for the PV, AV and DV variables is the dollar (US$).
* The result $\times 10^{-8}$.
** The result $\times 10^{8}$.

gasoline and ethanol are available. For energy consumption, diesel, fuel oil and kerosene can be found.

Another important characteristic of the Theil index concerns the construction of data. According to formula (2) in this work, the elaboration of the historical series for this index occurs with data for 2 years, for example: 1994/1995. In other words, so as to calculate the Theil index for 1995 it is necessary to know how much was consumed by the industries of each energy source and their respective prices for 1994 and 1995.

Fig. 1 confronts the evolution of the industries energy consumption (formula (1)) with the Theil index (formula (2)) in the period under study.

The economic measures proposed for this methodology are three: production value, added value and value of delivered goods.

Production value (PV) means the physical production of all industries multiplied by their respective prices for services or products. In other words, when analyzing data referring to the Brazilian accounts, in relation to the GDP, the production value would be the bulk (without discounts) of production. More precisely, looking at the GDP from the point of view of expenses and income, the PV would be equal to the industry GDP, plus the final consumption of the industry, minus the taxes on the products.

Most of the data obtained for the economic measures for production were taken from the IBGE site and some of them from the Banco Central do Brasil. The difficulty in working with these data refers to their aggregation. For example, in the IBGE and Banco Central do Brasil sites, it was not possible to find the industries final consumption. It was thus necessary to use mathematical techniques for obtaining these disaggregated numbers.

The added value is the difference between the production value (PV) minus the cost. As described in the methodology of this study, the cost would be the industries expenses with material and energy. However, to find these data disaggregated is not easy, as they are not always of public domain or from reliable sources. For this reason, in this research, the cost will be treated analogously to the calculation of the GDP,[10] that is, the value of production surplus.

The value of delivered goods, according to the methodology proposed, would be the production value minus the value of the inventories in constant ($) currency. The inventory should be understood as the value of the delivered goods. Table 4 shows the historical evolution of the economic measure indicators.

Fig. 2 shows the historical evolution of the three economic measures. There is a clear decrease between 1998 and 2000. The minimum point is found in 1999. This phenomenon is directly related to the energy crisis that occurred in that period of the recent Brazilian history. This period was called "apagão" (black out).

Table 5 presents the six energy intensity measures, as described in the methodology of this work.

Fig. 3(A) shows, in comparative terms, the division of the Theil index by the three economic measures. In turn, Fig. 3(B) shows the evolution of energy intensity Theil by Production Value. Analogously, Fig. 3(C) shows the ratio of the Theil index by the Added Value and Fig. 3(D) shows the division of Theil by Delivery Value.

Fig. 4(A) shows, in comparative terms, the division of energy consumption in Joules by the three economic measures. Fig. 4(B) shows the evolution of energy intensity Joules by Production Value. Likewise, Fig. 4(C) shows the energy intensity of energy

[10] According to IBGE, the definition of GDP would be "goods and services produced in the country, minus the expenses with the inputs used in the production process along the year. It is the measure of the total bulk added value generated by all economic activities".

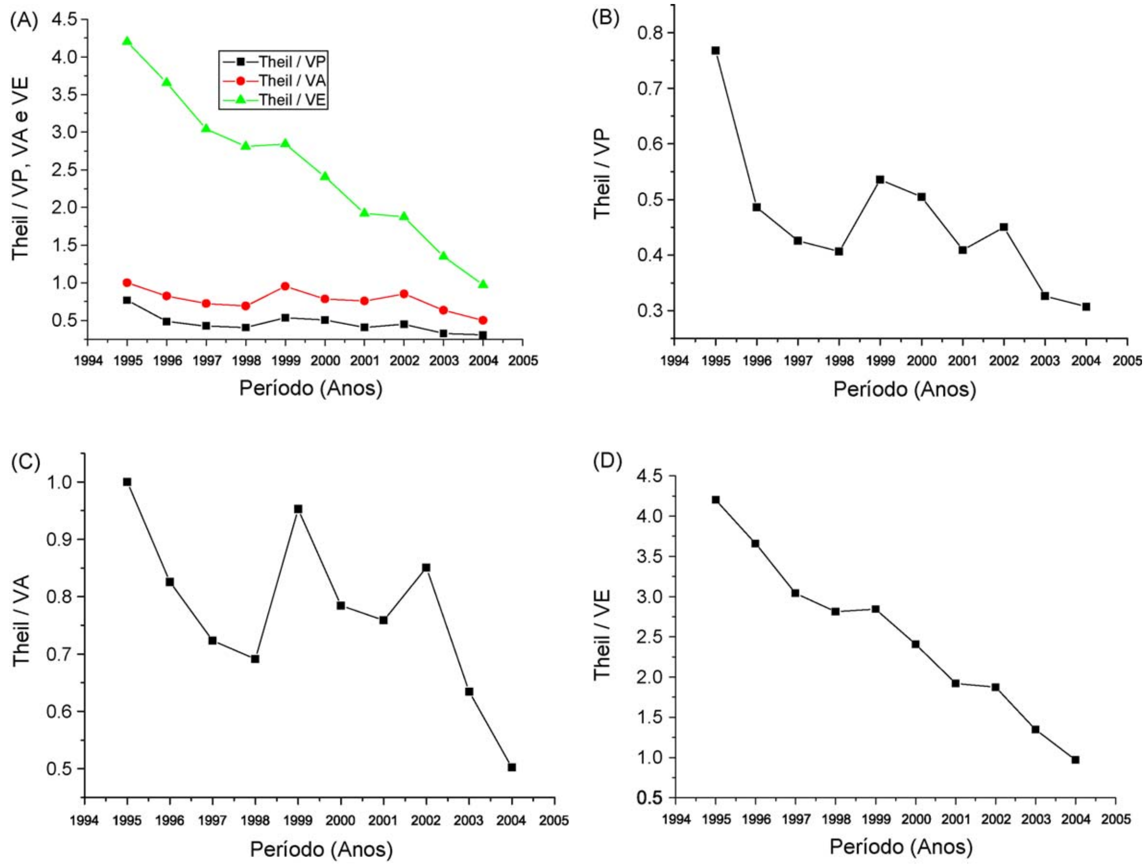
(A)
Theil / VP, VA e VE
Theil / VP
Theil / VA
Theil / VE
Período (Anos)
(B)
Theil / VP
Período (Anos)
(C)
Theil / VA
Período (Anos)
(D)
Theil / VE
Período (Anos)

Fig. 3.

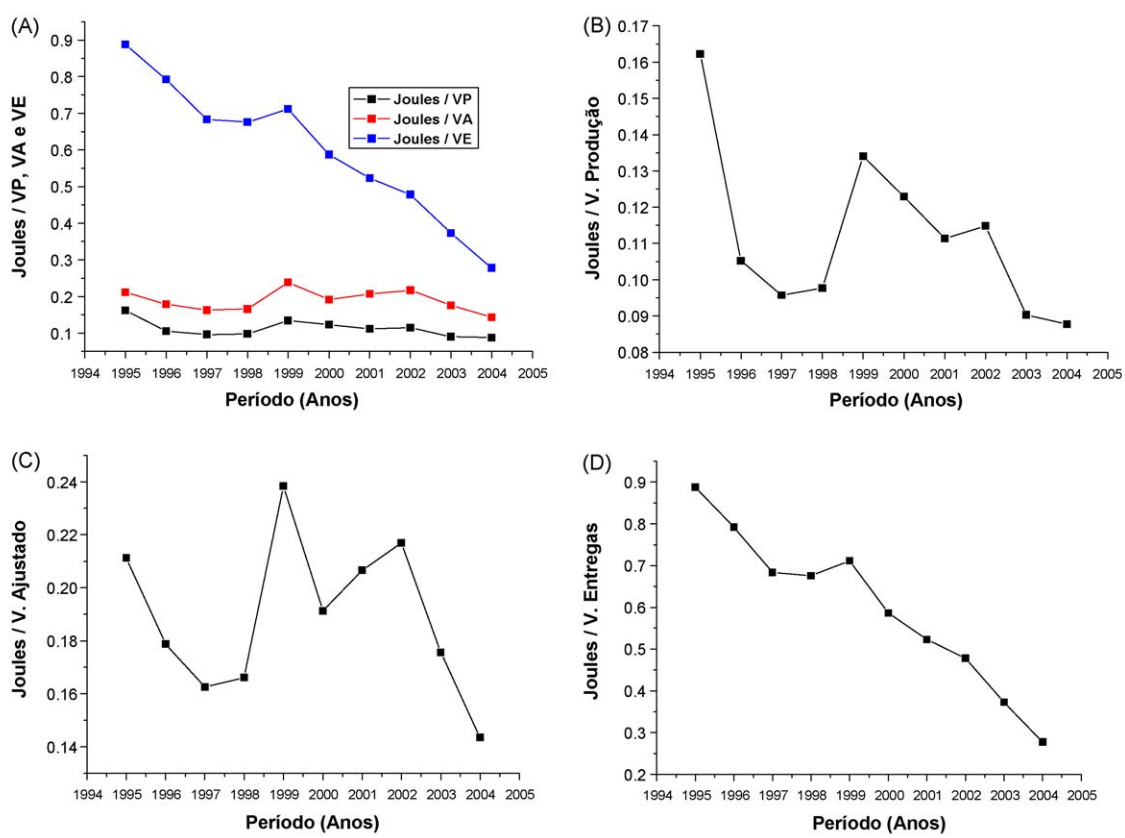
(A)
Joules / VP, VA e VE
Joules / VP
Joules / VA
Joules / VE
Período (Anos)
(B)
Joules / V. Produção
Período (Anos)
(C)
Joules / V. Ajustado
Período (Anos)
(D)
Joules / V. Entregas
Período (Anos)

Fig. 4.

Table 6
Simple statistics.

Variables (1995–2004)	Average	Standard deviation	Sum	Minimum	Maximum
Theil/Production V.	0.46184	0.12957	4.61837	0.30698	0.76773
Theil/Added V.	0.77236	0.14710	7.72364	0.50222	1.00012
Theil/Deliveries V.	2.50760	1.00805	25.07601	0.97165	4.20121
Joules/Production V.	0.11220	0.02288	1.12200	0.08771	0.16222
Joules/Added V.	0.18911	0.02906	1.89107	0.14350	0.23832
Joules/Deliveries V.	0.59887	0.18897	5.98867	0.27763	0.88773

Calculations conducted by the authors with the aid of the SAS (Statistical Analysis System) software.

consumption by the Added Value and Fig. 4(D) shows the division of energy consumption by the Delivery Value.

7. Statistical analysis [9]

The data obtained as from the methodology applied in this research, obtaining six energy intensity measures, become clearer and likely of analyses precisely in the comparison of the curves constructed. As it happens to be a comparative approach in a certain period ($n = 10$ years), two important statistical tools (concepts) are of great value: simple correlation and covariance matrix.

Table 6 shows the simple statistics of the variables treated. It is worth noting that the energy intensity measures observed below incorporate the data for the period going from 1995 to 2004. These statistics are important to manipulate more complex statistical methods, as the ones mentioned. The standard deviation measure for all the variables was satisfactory. The other measures served as an aid for the following calculations.

Table 7 presents the covariance matrix for the variables approached. So as to obtain a specific value for the correlation coefficient (r) between two variables, it suffices to follow the line and or column of the variable desired and contrast one with the other. For example, the correlation between years × Joule/AV is equal to $r = -0.18084$, with p-value equal to 0.6171. It is possible to find this value starting both from the line and from the covariance matrix column.

It is important to stress that, for this research, they will be considered as a strong correlation between two variables values p-value < 0.05 that is, with a 95% probability of there being a correlation. Otherwise, nothing can be affirmed about the correlation. The scheme below follows:

$H_0 : \text{Corr} = 0$ or $H_A : \text{Corr} \neq 0$;

See p-value:

- <0.05 = Rejects H_0; thus, the correlation exists and is likely of interpretations. The results are those expected.
- >0.05 = Accepts H_0; thus, there are no evidences to reject H_0. The results are discarded.

Once the methodology applied, six energy intensity measures are obtained, and the seventh variable happens to be the annual series. This variable is incorporated only for calculation purposes and does not alter the final result of the research. For all the variables, the correlation coefficient was calculated versus a historical series (time). In most cases, these coefficients present decreasing linear association between the variables. This shows a decreasing tendency in energy intensity of the segments of the industrial sector.

The energy intensity measures correlated below were discarded according to the correlation probability. Nothing can be stated for these variables. The following pairs of variables submitted to statistical correlation are:

1. Years × Joule/PV;
2. Years × Joule/AV;
3. Theil/PV × Joule/AV;
4. Theil/VE × Joule/AV;

The reciprocal is true for all cases, as mentioned in the scheme above.

When analyzing the energy intensity measure Joule/PV with time, there is nothing that can be stated. The correlation is unsatisfactory ($r = -0.52082$ and p-value = 0.1227) and, in general terms, no characteristic of this measure provides enough information on how this occurs. The same phenomenon occurs when analyzing the energy intensity measure Joule/AV and the same justification of consequence is valid.

However, when comparing these two pairs of measures with the others, the contrast is very marked. All the other correlations were satisfactory and, in some cases, present high correlation. For example, years versus Theil/VE ($r = -0.98644$ and p-value < 0.001) and years versus Joule/VE ($r = -0.97464$ and p-value ≤ 0.001). It should be detached that the minus sign in the correlation coefficient indicates a decreasing tendency whereas the positive sign indicates increase.

Thus the importance of the time variable in this research. When making the correlation of all the energy intensity measures with time, it can be stated that, in all cases in which the correlations were satisfactory, the tendency of the measures is decreasing. This means a positive leap towards energy efficiency.

The energy intensity of countries deemed developed is also decreasing in relation to time. This phenomenon is occurring

Table 7
Covariance matrix.

Variables	Years	Theil/PV	Theil/AV	Theil/VE	Joule/PV	Joule/AV	Joule/VE
Years	1	−0.73163	−0.64224	−0.98644	−0.52082	−0.18084	−0.97464
p-value		0.0162	0.0453	<0.001	0.1227	0.6171	<0.001
Theil/PV	−0.73163	1	0.88287	0.82012	0.95108	0.59464	0.81385
p-value	0.0162		0.0007	0.0037	<0.0001	0.0698	0.0042
Theil/AV	−0.64224	0.88287	1	0.74125	0.88902	0.85000	0.78103
p-value	0.0453	0.0007		0.0142	0.0006	0.0018	0.0076
Theil/VE	−0.98644	0.82012	0.74125	1	0.63401	0.29877	0.98941
p-value	<0.001	0.0037	0.0142		0.0490	0.4017	<0.0001
Joule/PV	−0.52082	0.95108	0.88902	0.63401	1	0.75567	0.65476
p-value	0.1227	<0.001	0.0006	0.0490		0.0115	0.0399
Joule/AV	−0.18084	0.59464	0.85000	0.29877	0.75567	1	0.38303
p-value	0.6171	0.0698	0.0018	0.4017	0.0115		0.2746
Joule/VE	−0.97464	0.81385	0.78103	0.98941	0.65476	0.38303	1
p-value	<0.001	0.0042	0.0076	<0.0001	0.0399	0.2746	

Calculations conducted by the authors with the aid of the SAS software.

mainly among developing (Brazil, India among others) and developed (OCDE) countries. In general terms, Brazil is spending less energy to generate the same wealth or more wealth in relation to time. In the cases detached, these measures are markedly satisfactory.

Table 7 shows that the correlations between the energy intensity measures, now excepting the variable year, were satisfactory in most cases and present positive correlation coefficients. This does not mean that the measures are not decreasing along time, but that, when compared, present similar qualitative behaviors. In other words, they indicate that they are following the same tendency.

Trying to explain the consequence of some energy intensity [15] measures not presenting satisfactory correlated results is a difficult task. Many macro and micro economic factors may influence these variables. Lack of investments, outdated infrastructure, high interest rate, quality of education, families' consumption power and several development rates seem to be the way. One of the most plausible hypotheses may be the energy crisis started in the country in the late 1990s. All the graphs shown in this study pointed to an increase in energy intensity for this period. This suggests that some energy intensity measures were more sensitive to this event than others. Nevertheless, a deeper analysis on this subject has to be conducted.

8. Conclusion

In the Brazilian industrial sector, in an aggregated way, most of the energy intensity indicators have presented similar behavior. A clear decreasing tendency concerning time is detached. It can be stated that this represents a qualitative improvement as to energy efficiency.

In a disaggregated way, the energy intensity indicators present a unified view of the direction taken by its evolution. In most cases, this tendency is noticeably positive. Several factors are related to energy intensity and to list possible deviations is not a simple task. A very reasonable hypothesis for the non-conclusive measures was the energy crisis started in the late 1990s, known as "apagão" (black out). It seems reasonable to state that some of these measures were more clearly perceived than others along the period.

However, this study on the consumption profile of the Brazilian industrial sector and of its economic activities indicates the presence de important deviations related to the yearly rate of change in energy intensity. Furthermore, there is no evident relationship between these deviations and the composition of the different energy intensity indicators. A more thorough study on the profile of these sectors is necessary in case the object of the study is to unveil such deviations.

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